

PROJECT CRAFTED: AN ADAPTED LESSON STUDY FOR PRE-SERVICE MATHEMATICS TEACHERS

Michael S. Meagher
Brooklyn College - CUNY
mmeagher@brooklyn.cuny.edu

Christopher Nazelli
Wayne State University
nazelli@wayne.edu

Asli Özgün-Koca
Wayne State University
aokoca@wayne.edu

Michael Todd Edwards
Miami University
edwardm2@MiamiOH.edu

Reports on a research project designed to implement an adapted Lesson Study cycle whereby pre-service mathematics teachers co-create a lesson with an experienced expert instructor and observe the instructor teach the lesson. Results show development in the pre-service teachers' attention to elements of planning such as anticipation and pedagogical choices during instruction.

Keywords: Teacher Education - Preservice, Teacher Knowledge

Introduction

This paper reports on a study designed to show how an adapted lesson study (Isoda, 2007) can enhance pre-service teachers' early experiences in constructing mathematical tasks for use in the classroom. Teachers engaged in lesson study assume shared responsibility for the teaching lessons they create, observe the effectiveness of these materials as they are taught, and then work to revise lessons for future use (Lewis, 2002). For the purposes of this study, *lesson study* refers to an improvement cycle in which teachers collaborate to set learning goals, study curricular materials, plan a lesson that will help students meet those goals, see the lesson taught by an experienced expert teacher, and reflect on its effectiveness using observational data and artifacts of student learning.

We have created and studied communities of planning and practice (Wenger, 1999), in a number of iterations, by implementing and studying a cycle of pre-service teachers designing lessons which promote inquiry and learning for understanding; the implementation of those lessons by a master teacher (observed by the pre-service teachers); and co-reflection on the lesson by the inservice and pre-service teachers (see e.g. Meagher, Özgün-Koca & Edwards, 2009; Meagher, Edwards & Özgün-Koca, 2011). Drawing on the different steps of the original instantiation of this process, we call this the CRAFTeD (Call for lesson; Referendum, Advising session; Fine-tune; Teach-Experience; Debrief) cycle. Based on a number of iterations of the process, we have found that the key component of this cycle is that pre-service teachers see their own Lesson Plan implemented by a master teacher which (a) gives them a different level of investment in the lesson than if they watched exemplary lessons, and (b) they see their lesson plan implemented without having the pressure of teaching the lesson themselves whereby their concentration may be alerted to such aspects as classroom management, teaching style, and their interactions with the students.

In studies undertaken in the past (Meagher, Özgün-Koca & Edwards, 2009; Meagher, Edwards & Özgün-Koca, 2011), we have studied the implementation of the CRAFTeD cycle with pre-service secondary mathematics teachers working with an experienced expert teacher to

design and implement a lesson for high school students. In the current study we report on 3 years of implementation of the cycle with pre-service secondary mathematics teachers, working with an experienced university professor, to design and implement a lesson for pre-service elementary mathematics teachers in a university content class for the latter group.

As in the previous studies, the research questions guiding the research and the analysis are:

- (i) how do pre-service teachers co-create a lesson with an experienced expert instructor, and
- (ii) what is the particular impact of ownership of the lesson on pre-service teachers' learning.

Literature Review and Relationship to Research

There is now a large body of literature (Fernandez, Cannon & Chokshi, 2003; Fernandez & Yoshida, 2004; Huang, Takahashi & da Ponte, 2019; Isoda, 2007; Lewis, Perry, & Murata, 2006) on the importance and effectiveness of lesson study approaches in improving teaching, curricular content, and instructional sequences. Hart, Alston & Murata (2009) draw on a plethora of research studies to argue that while many professional development models such as action research place teachers at the center of the research, lesson study is unique in the focus that is brought to bear on a “live lesson.” They assert that, during lesson study “teachers notice certain aspects of teaching and learning, and this implicit and organic noticing does not happen in artificially replicated professional development settings” (p.1). Lesson study approaches can also provide for more focused professional development than many traditional professional development models (Gersten et al., 2014; Lewis, 2002). Furthermore, developing communities of practice (Wenger, 1999) and lesson study groups (Fernandez, 2002) can help teachers to adopt a more research-based focus in their lesson planning and to develop a shared repertoire of communal resources which can transcend individual contributions. Most research thus far has focused on inservice teachers: our research involves implementing an adaption of the lesson study approach for pre-service teachers.

Our research applies lessons learned from lesson study approaches to address the problem that teaching methodologies advocated by methods instructors in teacher preparation programs are not readily observed by pre-service teachers in actual classroom settings, a disconnect that has become more pronounced in the age of high-stakes standardized testing. While university methods instructors laud the merits of student-led inquiry, exploration, and discovery-based teaching methods, secondary mathematics teachers in too many schools “set aside” such teaching in favor of instruction directly focused on student preparation for high-stakes, multiple choice state tests (Seeley, 2006). In an age where testing dominates the landscape of too many classrooms, it becomes increasingly difficult to provide teachers-in-training with models of high-quality mathematics instruction in school environments. The proposed study explores a possible response to this situation. As secondary-level math PSTs construct lessons to be taught to prospective elementary school teachers with the guidance of their mathematics education professor, all parties benefit. The secondary-level teachers learn nuances of planning, implementing, and assessing instruction. The prospective elementary teachers gain a deeper understanding of the content that they will soon explore with their own students. By providing pre-service teachers with opportunities to collaborate across grade levels, we create synergies that lead to deeper understanding of content and pedagogy.

Methods and Methodologies

The cycle

The design of the CRAFTeD cycle is as follows:

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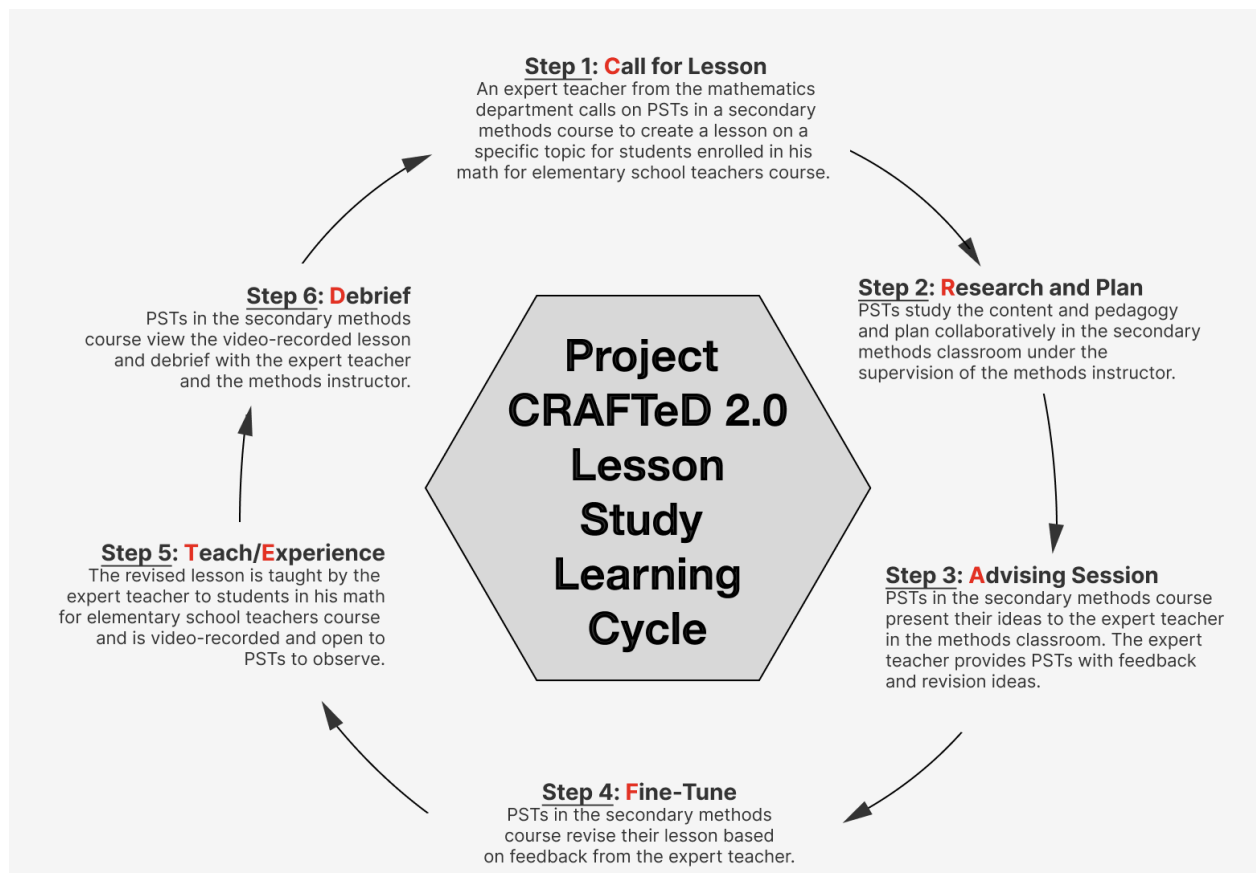


Figure 1: The CRAFTeD Cycle

The basic sequence of the original cycle and the revised cycle is (i) A class of pre-service high school teachers write Lesson Plans on a given topic and then worked together to develop improved lessons/short units designed often for technology-rich environments; (ii) an experienced expert instructor reviews the lessons/short units and presented an initial redesign; (iii) the experienced expert instructor teaches the lesson, observed in person or on video by the pre-service teachers; (iv) the pre-service teachers and the experienced expert instructor meet together to reflect on and redesign the lesson based on their experiences in the classroom.

In changing the target population of the lessons from high school students to pre-service elementary teachers and drawing on previous experiences with the cycle, there were a number of noteworthy changes in our approach.

(a) The content of the lesson was now to be taken from the mathematics curriculum for elementary school teachers (e.g. comparing partitive and quotitive models of division for whole numbers). As we will see below in the data analysis this provided some interesting challenges for the secondary pre-service teachers as they thought about elementary content in a deep conceptual manner.

(b) Rather than planning multiple lessons and then voting to select a single lesson during what had been called the Referendum stage, the class, which tended to be relatively small, worked as a whole group on the lesson.

(c) The new version of the cycle placed greater emphasis on researching and studying curriculum with a bank of research papers related to the topic created for the class to work with.

The purpose of the cycle is to examine:

- (i) how do pre-service teachers co-create a lesson with an experienced expert instructor, and
- (ii) what is the particular impact of ownership of the lesson on pre-service teachers' learning.

The pre-service secondary teachers (i.e., research lesson planners)

The pre-service secondary mathematics teachers (c. $n=12$ for each of three years) were engaged in routine activities that comprise a mathematics teaching methods course, which met for two 75-minute sessions each week for 15 weeks, at a large public Midwestern university. The methods course was one of a two-course methods sequence; these courses being the pre-service teachers' only methods courses in the program. Prior to taking or along with the methods courses the pre-service teachers take foundations of education and mathematics content courses. The course was designed specifically for pre-service secondary school mathematics teachers, who engaged in activities focused on pedagogical issues (e.g., constructing lesson plans and grading rubrics, creating technology-oriented math activities) and content issues (e.g. solving mathematics problems, assessing student work). As part of the course the pre-service secondary teachers engaged in one iteration of the CRAFTeD cycle.

The pre-service elementary teachers (i.e., students experiencing the research lesson)

The pre-service elementary teachers (c. $n=12$ for each of the three years) were engaged in a mathematics content course which met for four 50-minute sessions each week for 15 weeks, at the same university. This course was one of a two-course sequence which all pre-service elementary teachers, regardless of specialization (e.g. Language Arts, Early Childhood), are required to complete. The students, typically first years and sophomores, take these courses early in their degree programs. The course focused on developing the pre-service elementary teachers' mathematical knowledge for teaching (Ball et al., 2008), and grounded that development in the core elements of the elementary school curriculum (e.g. operations on the real numbers). Each week, the pre-service elementary teachers worked in small groups on problem sets that required them to push beyond "the tacit understanding that characterizes and is sufficient for personal knowledge and performance" (Ball, 2000, p. 245). The lesson created by the secondary pre-service teachers, therefore, was planned to fit into this weekly problem-set activity schedule.

The teacher of the research lesson

The teacher of the lesson was a professor in the mathematics department of the large public Midwestern university. He and the instructor of the secondary mathematics teaching methods course had nearly a decade of experience co-facilitating lesson study cycles with inservice K-12 teachers from local school districts. In addition, the two instructors collaborated on the development of the mathematics content course and its weekly problem-set activities.

Data Collection

The data collected during each CRAFTeD cycle in order to answer the study's research questions were:

- Field notes from an in-class visit by the expert instructor who initiated the cycle
- Curriculum study exchanges via an online discussion board
- Lesson Plan created by the pre-service teachers
- The revisions suggested by the expert instructor via an in-class visit
- Revisions of the lesson plan by the pre-service teachers

- The final implemented Lesson Plan
- Videotape and fieldnotes from the lesson as taught by the expert instructor
- Field notes from the debriefing sessions between the pre-service and expert instructor.
- Reflection papers by pre-service teachers on the entire cycle.

Analysis

Using the coding book from the previous versions of the project, the data was initially coded through a deductive coding process for direct answers to the research questions with two basic codes: “cocreation” (CC) and “their own lesson” (TOL) as well as codes for each stage of the cycle. The data was then re-analysed using open coding and the constant comparative method (Cresswell & Poth, 1998) to examine emerging patterns within the broad categories of the first round of coding. Sub codes such as Classroom Management, and Pedagogical Choices emerged at this stage. Quotes exemplifying the quotes were organized and exemplary quotes for each of the codes chosen to support the analysis. The analysis is presented in the order of the cycle.

Results

Call for Lesson

The Call for a Lesson occurred during the second week of the university semester. The call was for a lesson to be implemented in a mathematics content class for elementary education students, not for 6-12 grade students. As noted earlier, the mathematics content class focuses on developing the pre-service elementary teachers’ Mathematical Knowledge for Teaching (MKT) (Ball et al., 2008); for example, the curriculum focuses on comparing partitive and quotitive models of division for whole numbers rather than learning to perform the standard algorithm for division. The expert instructor, who was from the mathematics faculty, visited the class in-person or virtually to inform the secondary PSTs about the nature of the class, its curriculum and students and share the topic of the lesson. He also shared what would be covered by the day of the lesson and related textbook pages. In each iteration of the cycle, the most striking aspect of the Call for a Lesson was the pre-service teachers’ reaction to the content which they expected to be trivial for them. As the cycle progressed we saw the challenge the content presented for the secondary pre-service teachers. We see this exemplified in the following PST quote from 2019: “The idea of building a lesson plan based on subtraction at first seemed easy, but there is a lot of thinking involved when explaining how to subtract two numbers. Because we are math educators doing mental subtraction in our head or solving a subtraction problem on paper seemed simple but when breaking down the math problem we must take into account that we are trying to explain to younger students.”

Research and Plan

Following the Call for the Lesson the secondary PSTs take 20-25 minutes in the next series of lessons (5-6 weeks) to work as a whole class on the lesson. The secondary PSTs learned from each other, as they synthesized different ideas and experiences, and this process began to normalize collaboration in teaching. There were also inherent challenges, such as limited time and space for individual contribution. During the three iterations of the cycle the number of PSTs has been approximately 12 so this was manageable as a whole class activity.

A key aspect to the Research and Plan step of the cycle was the time spent on engaging in research on best practices for teaching the content of the lesson. An online discussion forum was created which was used to locate/share resources and to allow asynchronous brainstorming about the lesson. This discussion centered on both content and pedagogical aspects of the lesson

including the study of materials from practitioner journals, youtube videos, internet resources, and selections from the research literature that focus on elementary teachers' mathematical knowledge on the topic of the research lesson.

The research phase, in each iteration, was an eye-opening experience for the PSTs in the richness of the seemingly straightforward topic for the lesson. They might think of an operation, e.g. subtraction or division of whole numbers, from a purely procedural perspective; but, when they began researching the conceptual underpinnings, they were challenged and humbled as they sought profound understanding of fundamental mathematics (Ma, 2010). As one PST in the 2019 cohort put it "Going into the lesson study, I thought subtraction was a fairly simple topic and that just reading the material provided by [the instructor] was simple enough. It wasn't until after we researched the topic and found articles such as "Subtraction: More Than Just Take Away", by Snow, that I realized how important the wording of problems can be."

This phase also engaged the PSTs in developing their MKT as they began to consider more closely how someone learns about the meaning of subtraction and where they might have difficulty. This PST Quote from 2019 reflects a locus of learning for many of the PSTs: "By investigating more about the topic, we learned what students typically struggle with, and we were able to incorporate this . . . into our lesson plan."

Advising Session and Fine Tune

An advising session with the expert instructor to discuss the draft lesson plan was scheduled for the middle of the semester (roughly the seventh week). This 30-45 minute session took place during a regular methods class meeting time. The draft lesson plan was shared with the expert instructor before this in-class visit, so that he can review it and formulate initial questions and feedback. When the expert instructor visited, one of the PSTs introduced the research lesson plan including the reasoning behind some of the design decisions. Following that, the expert instructor shared his critique, suggesting improvements orally as the PSTs took notes.

Receiving critical feedback was not easy at first. This PST Quote from 2019 typifies the PSTs reaction: "Once we had finished our rough draft of the lesson and presented it to [the expert instructor], I was completely taken aback by the amount of constructive criticism he had towards our lesson. I thought we had put together this amazing lesson where we not only required our students to think but also have explanations and representations for their thinking processes, only for [the expert instructor] to come in and nitpick all of the details we had so carefully constructed. He asked us questions regarding our wording and our timeline of the lesson that I had not even thought about, but once we took those questions into account our lesson came out even stronger." By training the attention of the PSTs to details such as the clear wording of questions and the appropriate amount of time needed for a productive, inclusive, whole-class discussion, they began to appreciate the amount of detailed, thoughtful, behind-the-scenes work involved in effective lesson planning.

The Fine Tuning of the lesson was done collaboratively and occupied approximately 25 minutes of each class in the weeks leading up to the teaching of the research lesson. The revised research lesson plan was shared with the expert instructor a week before implementation, providing an opportunity for him to share any last minute questions or concerns and make any needed adjustments.

Teach/Experience

The research lesson was taught by the expert instructor; and was recorded using Swivl. The secondary PSTs were invited to observe the research lesson in-person and take field notes. Usually 2-4 PSTs observed the lesson in person and those who were unable to attend the live

lesson, watched the recording. As is the custom in a research lesson, the PST observers did not engage with the students but concentrated on collecting evidence of their learning (e.g. through their work and peer discussions). Even though the expert instructor enacted the planned research lesson faithfully most of the time, there were times when he deviated from the plan, typically through in-the-moment decisions such as choosing to explore a novel, unanticipated student idea or suggestion.

The key aspect of the teaching stage of the lesson is the level of investment the PSTs bring to the experience. In teacher education programs lesson plans are typically abstract exercises and are never taught. The CRAFTeD cycle provides the opportunity to see the lesson taught and it is a deeply meaningful experience for the PSTs. As one PST in a Quote from 2019 put it: "For most of the education classes I've taken thus far, I have created lesson plans, but I have never been able to actually see one through, so being able to watch this lesson come to life was very exciting. While it was cool to see certain things in the lesson go well, it was also helpful to see the snags in the lesson as well."

In planning for the lesson the PSTs picture how it might be taught and, therefore, they are able to notice and value the pedagogical choices made by the expert instructor. For example, this PST Quote from 2019: "One thing I had not thought much about were transitions from one activity or thought process to the next. [The expert instructor] did this so well." The PSTs also saw value in how the expert instructor was able to implement research-based best practice strategies they had discussed in the research phase of the cycle. This PST Quote from 2021 is typical of the connections the PSTs made: "From our in-class discussion of Arbaugh (2010): 'A teacher who revoices students' ideas can clarify a mathematical relationship, identify or insert important mathematical vocabulary, or allow a misconception to be a place for learning' (p. 46). [The expert instructor] took special care in revoicing the student ideas that were presented into solid information for everyone. He did not create the knowledge, the students did that, but he made sure to repackage it for everyone to grasp it and walk away with the same understanding." Other PSTs reflected other aspects of the teaching such as in this PST Quote from 2020: "In the actual lesson, [the expert instructor] told the students to 'represent' multiple ways. I think that was a really good word for this because the students ended up trying to visually show the different ways they solved the problem. This reminded me of our 'Developing Symbolic Meaning' (Lapp et al., 2013) reading where they discussed that providing representations of mathematical ideas internalizes those ideas for students."

Debrief

During the first class after the research lesson, the expert instructor visited the methods class and participated in a 45-minute debrief (i.e. a post-lesson discussion). Staying true to the typical lesson study structure, the enacting teacher, in this case the expert instructor, shared his thoughts on the research lesson first. Following that we opened up the floor to PSTs to share their observational data and takeaways. The discussion usually centered around positives (what worked), what went according to plan, what could be improved, and what changes would lead to that improvement. Reflection on the lesson and plans for improvement are an important aspect of the lesson studies and its importance was recognised by the PSTs, for example in this Quote from a PST in 2021: "Lastly, this study showed me the importance of reflection. Upon reflecting on this lesson, I am able to see what could have gone more smoothly and what went well. This reflection can inform future lessons with my students and can allow me to make changes if I teach this lesson again. Reflecting can also allow me to see what I should have anticipated and can help me better predict my students' responses."

Analysis & Discussion/Conclusion

This study was designed to implement the six stage CRAFTeD cycle we developed to provide pre-service teachers enrolled in a mathematics methods class a rich and meaningful experience in writing lesson plans and to answer the following research questions: (i) how do pre-service teachers co-create a lesson with an experienced expert instructor? and (ii) what is the particular impact of ownership of the lesson on pre-service teachers' learning?

This study was not on a large scale but the data presented above provides evidence that there is a tangible development in understanding of lesson planning as well as many basic and more nuanced issues of teaching when the CRAFTeD cycle is implemented.

The key benefits of the CRAFTeD cycle, and the findings in response to research question (i), as evidenced in the three iterations reported on in this paper and in answer to the research questions are (a) particularly in the collaboration with the expert instructor, the development of the PSTs' MKT as they research the content of the lesson in the framework of elementary content from an advanced viewpoint (b) the investment the PSTs make in the lesson knowing that it will be actually taught and the enhanced ability for writing a lesson plan to be a learning experience because of the full CRAFTeD cycle.

In regards to the relationship with the expert instructor, as was seen in the quotes above that were typical of the PSTs experience, the instructor's framing of his class to emphasize MKT was very beneficial to the PSTs. This framing, and their research on their lesson topic, developed key components of MKT such as knowing multiple representations of a concept, knowing common misconceptions for students learning the topic, and knowing how a particular topic fits with learning trajectories for that topic. The other main positive aspect arising from the relationship with the expert instructor was the quality of the feedback on their work and the necessity of working with the feedback since the lesson will actually be taught.

In regards to the impact of the ownership of the lesson on pre-service teachers' learning i.e. the findings in response to research question (ii), as can be seen in the quotes in the results section the PSTs clearly had a very different level of investment in the quality and impact of the lesson since it would be a live lesson. This level of investment manifested both in the construction and writing of the lesson but, perhaps more importantly, in observing the teaching of the lesson: the PSTs were highly attuned to the pedagogical choices of the expert instructor as well as being highly attuned to the learning of the students engaged in the lesson.

We believe the CRAFTeD cycle provides a variant model on traditional Lesson Study that can be very effective in the development of pre-service teachers.

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